NONDESTRUCTIVE EVALUATION OF RADIOACTIVE WASTE DRUMS CONTAINING MISCELLANEOUS WASTE FORMS

John Steude, Ed Strickland, Dee Summers, & Ruben Reyes
Scientific Measurement Systems, Inc.
2209 Donley Drive
Austin, Texas 78758

INTRODUCTION

Vast quantities of radioactive waste materials have been generated as a result of the production of nuclear energy and defense materials over the past five decades. It is estimated that there are over 1.4 million buried and stored drums of radioactive waste within the U.S. Department of Energy complex [1,2].

To ensure that drums do not rust and leak or otherwise release radioactive liquids and vapors into the environment, low level waste regulations [3] require that containers have less than 1 percent free liquids. For transuranic wastes, the waste acceptance criteria for the Waste Isolation Pilot Plant in New Mexico requires that any container entering the facility must have less than 1 percent free liquids [4]. This requirement has had various interpretations. One such interpretation is that a container within a container must have less than 1 percent liquid.

The most practical means to certify that waste drums meet waste acceptance criteria is with a nondestructive evaluation (NDE) method. Opening drums for inspection and certification is not practical from either a safety or a cost basis because it is labor intensive and additional wastes may be generated in the hot-cell where the inspection takes place.

The objective of this paper is to present NDE results for a simulated radioactive waste drum with miscellaneous contents. The methods demonstrated are X-ray imaging and analysis utilizing digital radiography (DR) and computed tomography (CT) to visualize and quantify free liquids in a simulated waste drum. Results are presented for an innovative radiographic method, recently developed by Scientific Measurement Systems, Inc. (SMS), for identifying free liquids.

Review of Progress in Quantitative Nondestructive Evaluation, Vol. 12
Edited by D.O. Thompson and D.E. Chimenti, Plenum Press, New York, 1993

The innovative DR method utilizes drum manipulation and digital image processing techniques. There is currently an SMS patent pending for this method.

METHODS

Although a single digital radiograph reveals the identity of many items in a waste drum, it cannot conclusively identify free liquids without additional information. Consequently, SMS has developed a simple digital radiographic method that is both fast and conclusive. This method is: (1) obtain a digital radiograph of a drum, (2) tilt the drum a few degrees, (3) obtain a second digital radiograph of the tilted drum, (4) digitally overlay and subtract one radiograph from the other. Because the liquid surfaces will remain horizontal relative to their containers in both the untilted and tilted drum, digitally rotating one image to overlay the other artificially tilts one set of liquid surfaces. Subtraction of the images conclusively identifies liquids in a drum with a positive/negative "fingerprint" where the difference between the two images is the shifted liquid surfaces.

To test DR and CT inspection techniques for finding and quantifying free liquids, a standard 208 liter (55 gallon) drum was filled with simulated miscellaneous waste items. Once free liquids are located with DR, CT imaging is used to quantify the free liquid volume. The combined DR/CT approach has the added advantage of being able to measure liquid and container volumes to quantify compliance with the waste acceptance criteria for no more than 1 percent free liquids. CT imaging is also used to clarify confusing contents within a waste drum.

All of the DR and CT images presented were obtained with an SMS Model 201 Computerized Industrial Tomographic Analyzer™. The standard Model 201 is designed to handle objects up to 150 CM in diameter. The particular Model 201 used in this project is equipped with a 420 kV X-ray tube. Aperture settings for detector collimators were 2 mm by 2 mm. Scan times were 5 minutes for either a single CT image or an entire drum DR image.

RESULTS

Figure 1 shows a DR image of a simulated waste drum. A review of the radiograph in Figure 1 shows that there are a number of partially filled containers in the drum. It is possible to distinguish the containers with liquids from those with powders due to the fact that the liquids have smooth horizontal surfaces while the powders have rough irregular surfaces. The powdered chemical samples are located in Figure 1 at the bottom of the drum at the extreme left and right and the center. The dry clay powder sample on the far right of the middle layer is also identifiable by a rough surface. Figure 2 shows an enlarged view of a second drum with contents similar to the drum shown in Figure 1.

Figure 3 is a CT image obtained at a height slightly above the liquid surface in the propane torch on the bottom left of the drum. The items numbered in Figure 3 are: (1) aerosol paint cans, (2) TCE bottle, (3) small halon fire extinguisher, (4) kerosene bottle, (5) CCL_4 bottle, (6) mineral oil, (7) propane torch, (8) thin plastic jar with clay powder, (9) thin plastic jar with water, (10) ethylene glycol bottle, (11) CO2 fire extinguisher, (13) plastic water bottle, and (14) chloroform bottle.

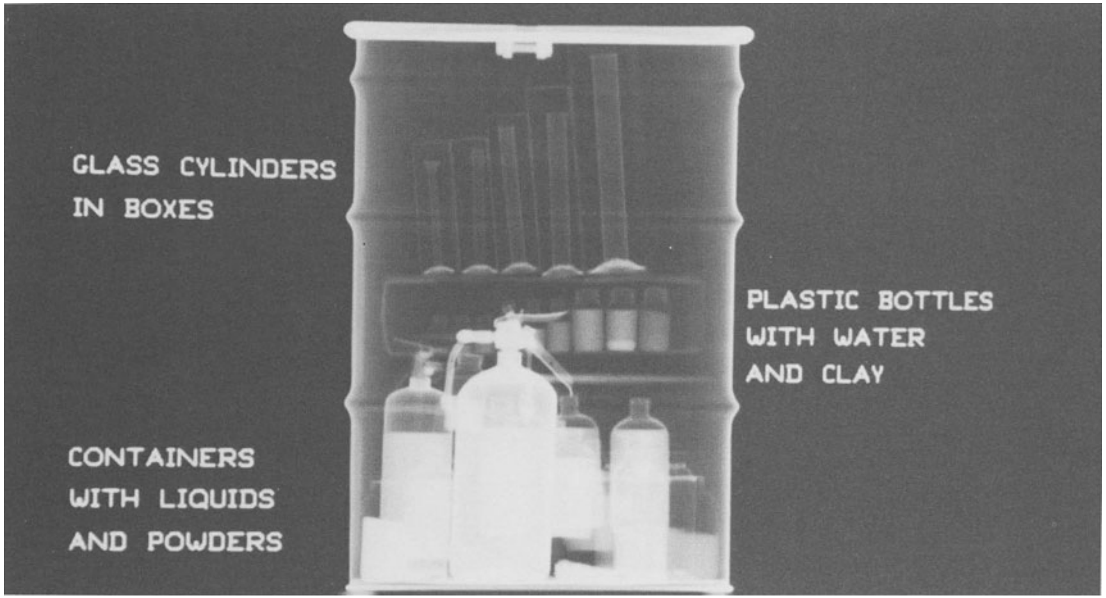

Figure 1 - Digital radiograph of a simulated waste drum.The bottom layer of the drum contained pressurized containers (e.g., fire extinguishers, a propane torch, and aerosol cans), bottles partially filled with powdered chemicals, and laboratory bottles partially filled with liquid chemicals. The middle layer of the drum contained plastic bottles with various amounts of water, saturated clay powder, and dry clay powder. The top layer contained various sized laboratory glassware with 1 percent residual water.

Figure 2 - Enlargement of a simulated waste drum digital radiograph.

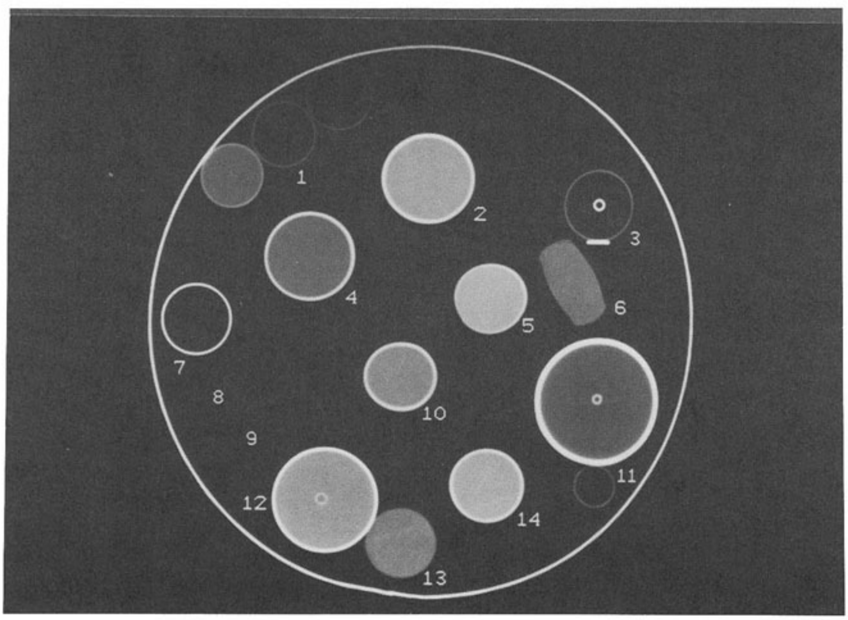

Figure 3 - Computed tomography image of drum shown in Figure 2.

Figure 4 shows a digital radiograph similar to the one in Figure 2, except that it was obtained by using the tilted/non-tilted image processing method. The free liquid surfaces are clearly identified by a black and white bar where they shifted relative to their containers. Note that the surfaces of powders in the jar behind the propane torch on the left and in the dry chemical fire extinguishers next to the propane torch slightly settled. This effect is distinguished by the rough black surface instead of the polarity of the black and white bar associated with shifted liquid surfaces. A major advantage of the technique is demonstrated in the center of Figure 4 where 3 liquid surfaces are detectable in 3 containers (i.e., containers 2, 10, and 13 in Figure 3) that have overlapping images due to their position in the drum with respect to the viewing angle.

The sensitivity of DR can be seen in the enlarged image of the glass cylinders containing 1 percent water by volume. An enlargement of the image in Figure 2 in the vicinity of the cylinders is shown in Figure 5. The bottoms of the cylinders are shaped like the top half of a bubble (i.e., hemisphere). It is possible to see the water level (gray) on both sides of the glass hemispheres (white).

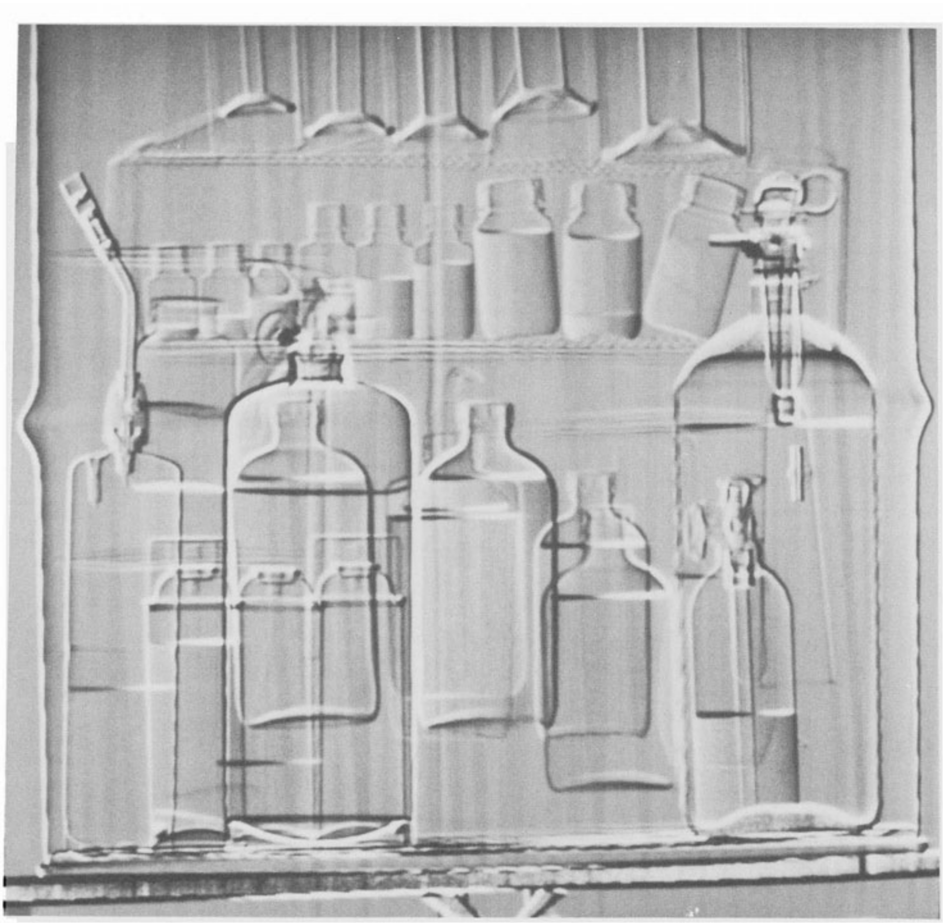

Figure 4 - Digital radiograph of waste drum after tilting the drum, obtaining a second radiograph and subtracting the tilted image from the non-tilted image.

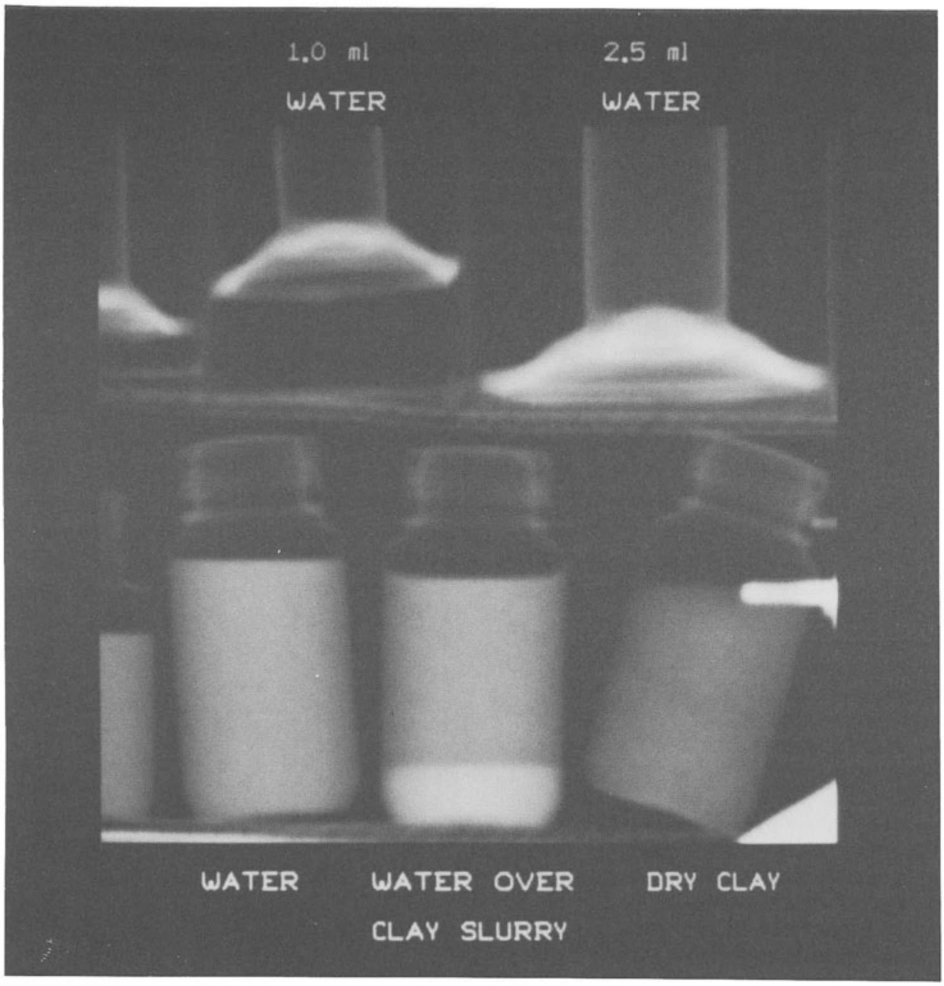

Figure 5 - Enlarged localized view of the digital radiograph in Figure 2.

Figure 6 shows the same view as Figure 5 after the tilt/non-tilt image processing. It is possible with this image to identify the black and white signal associated with the shifting of 1.0 and 2.5 ml of water. Figures 6 also shows that the clay slurry in the plastic jar also produces the black and white signal. The dry clay powder at the bottom right is identified by a black rough surface that indicates it may have settled during the handling of the drum between images.

To demonstrate that free liquid can be quantified, the CT images shown in Figure 7 were taken in the vicinity of the 2.5 ml of water identified in Figure 5 and 6. A standard SMS software program called "SOLID" was used to measure the water in each image, indicated by the gray inside of the white shaded glass, and interpolate between the heights of the CT images to estimate a total liquid volume. The volume estimated was 2.25 ml. This particular estimate was in error by 10 percent, but it represented a good test of the technique because it was used on a small amount of liquid in an odd shaped volume. A similar technique can be used to estimate the volume of the container with a few CT images. This type of liquid and container volume estimate could be used to certify compliance with waste acceptance criteria in a quantitative manner without manually disassembling drums.

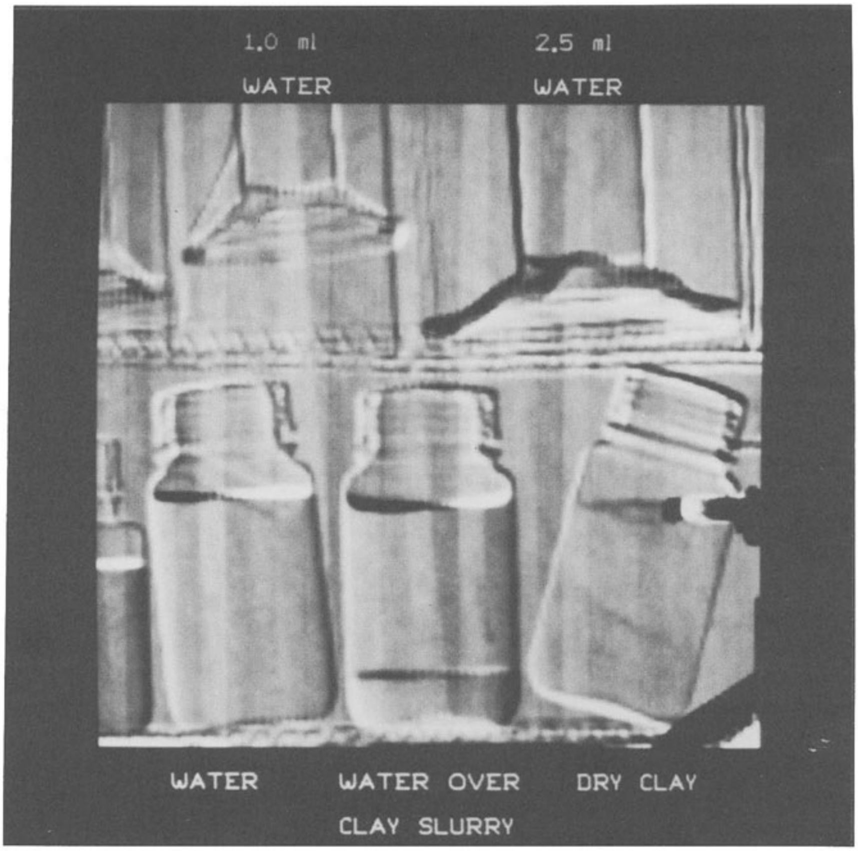

Figure 6 - Enlarged localized view of subtracted radiograph shown in Figure 4.

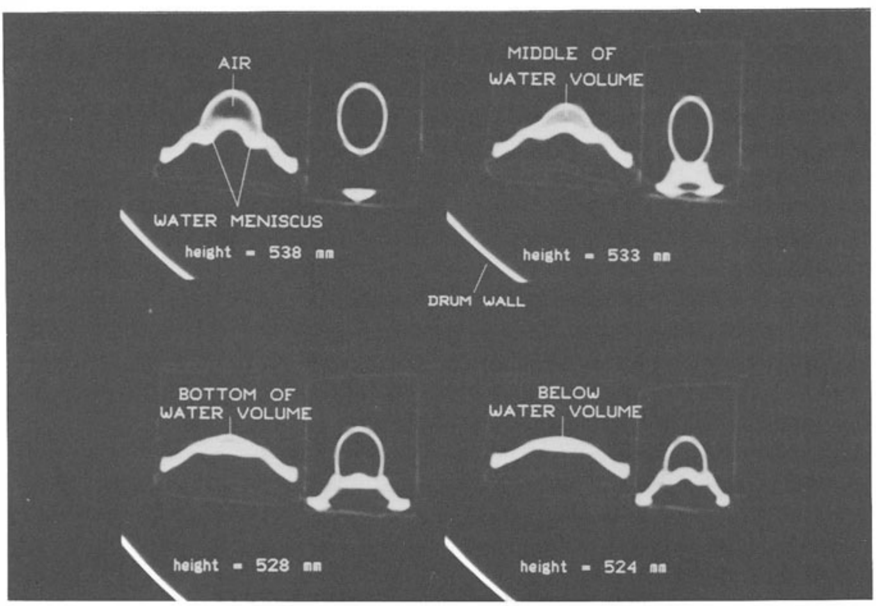

Figure 7 - Enlarged views of CT images near the bottom of a 250 ml glass cylinder.

SUMMARY AND CONCLUSIONS

An innovative method utilizing image processing of digital radiographs of tilted and non-tilted drum to detect free liquids was demonstrated. Demonstration of the method was successful at identifying a variety of free liquids in various types of containers. The method successfully detected a liquid volume as small as 1.0 ml in a glass cylinder inside a 208 liter drum.

The complimentary use of CT imaging with DR imaging was demonstrated. Quantitative CT imaging and analysis was utilized to provide an liquid volume estimate. The CT method successfully estimated a volume as small as 2.5 ml within a 10 percent error.

Future development of DR and CT inspection of waste drums should concentrate on the optimization of the scanner for to decrease drum inspection times. Minor improvements in the scanner, such as increasing the number of detectors and decreasing the X-ray source to detector distance for scanning drums, will reduce the scan time from 5 minutes per image to approximately 1 minute per image with the SMS Model 201 scanner. This will undoubtedly result in an inspection technology that is the most cost-effective for certification of drums for compliance with the waste acceptance criteria for free liquids.

Radioactive waste management is publicly perceived as a difficult problem demanding the best available inspection technologies to assure environmental and public safety. Nondestructive DR and CT imaging are exceptionally sensitive and applicable inspection technologies that are currently available without the need of extensive development.

ACKNOWLEDGEMENTS

The authors wish to thank Ed Acosta, Tom Avina, Paul Cavazos, Mark Davis, and Rudy Garcia for their assistance and cooperation in providing access to the SMS Model 201 CITA in the CT facility at Kelly Air Force Base. The efforts of Glenn Meyer of SMS are also greatly appreciated. Harvey Welch and Don Pound of EG&G Idaho and Jim Weber of Westinghouse Hanford Company provided valuable information on the typical contents of radioactive waste drums.

REFERENCES

1. Integrated Data Base for 1990: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics. Report prepared for the DOE Office of Civilian Radioactive Waste Management and Office of Environmental Restoration and Waste Management.

2. United States Department of Energy Environmental Restoration and Waste Management Five Year Plan, Fiscal Years 1992-1996, June 1990.

3. 10 Code of Federal Regulations, Part 61.56(a)(3).

4. TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant, WIPP/DOE - 069, Revision 3, UC - 70, Westinghouse Electric Corp., 1989.